CHM 113 General Chemistry I

Key

Empirical Formulas and Combustion Practice Problems

1) Two compounds have the same composition: 92.25% C and 7.75% H. [Assume 100.0g]

a) What is the empirical formula?

92.25g 7.75g

need moles

$$92.25\text{g C} \times \frac{1\text{mol C}}{12.00\text{g C}} = 7.681\text{ mol C} \leftarrow \text{smaller \#}$$

$$7.75\text{g H} \times \frac{1\text{mol H}}{1.00794\text{g H}} = 7.69\text{ mol H}$$

$$\frac{7.681\text{ C}}{7.681\text{ C}} = 1 \qquad \frac{7.69\text{mol H}}{7.681\text{ mol C}} = \frac{1.00\text{ H}}{1\text{ mol C}}$$

Empirical Formula = CH

b) One compound has a molecular weight of 52.03 amu, the other of 78.05 amu. What are the molecular formulas?

1) Find multiple = $\frac{\text{molecular weight}}{\text{empirical weight}}$

2) Multiple (Empirical Formula)

Compound #1: 52.03 amu

Compound #2: 78.05 amu

empirical weight = 1(C) + 1(H) = 1(12.0107amu) + 1(1.00794amu) = 13.0186amu

#1) $\frac{52.03\text{amu}}{13.0186\text{amu}} = 4$

#2) $\frac{78.05\text{amu}}{13.0186\text{amu}} = 6$

molecular formula = 4(CH) = C_4H_4 #1 compound

molecular formula = 6(CH) = C_6H_6 for #2 compound

2) Adipic acid is used to manufacture nylon. The composition of the acid is 49.3% C, 6.9% H, and 43.8% O by mass and the molecular weight is 146 amu. What is the molecular formula?

Know
Adipic acid - mw = 146 amu
49.3% C
6.9% H
43.8% O
* Assume 100 g

want molecular formula
↓ multiple
Need empirical formula

empirical formula from molar ratios

$\frac{2.740}{2.740} = 1\ mol\ O$ $\quad \frac{6.9\ H\ mol}{2.74\ mol\ O} = 2.5\ mol\ H$

Not whole #: need to multiply

$\frac{4.10\ mol\ C}{2.74\ mol\ O} = 1.5\ mol\ C$

$.493 \times 100.\,g \times \frac{1\ mol\ C}{12.0107\ g} = 4.10\ mol\ C$

$.069 \times 100.\,g \times \frac{1\ mol\ H}{1.00794\ g} = 6.85\ mol\ H = 6.9\ mol\ H$ (sig figs.)

$.438 \times 100.\,g \times \frac{1\ mol\ O}{15.9998\ g} = 2.74\ mol\ O$ * smallest #

$C_{1.5} H_{2.5} O_1 \times 2$

$C_3 H_5 O_2$ ← All whole #s

empirical formula

empirical weight = 3(C) + 5(H) + 2(O)
= 3(12.0107 amu) + 5(1.00794 amu) + 2(15.9988 amu)
= 73.0714 amu

molecular formula / empirical weight → $\frac{146\ amu}{73.0714\ amu} = 2 \times (C_3H_5O_2)$

molecular formula $C_6H_{10}O_4$

3) The characteristic odor of pineapple is due to ethyl butyrate, a compound composed of C, H and O. Combustion of 2.78 mg of ethyl butyrate produces 6.32 mg of CO_2 and 2.58 mg of water. What is the empirical formula of the compound?

Know
ethyl butyrate
C, H, O

want
empirical formula
↳ need moles C, H, O

ethyl butyrate + $O_2(g)$ → $CO_2(g)$ + $H_2O(g)$
2.78 mg → 6.32 mg, 2.58 mg

I. find moles

C) $6.32\ mg\ CO_2 \times \frac{1\ g}{1000\ mg} \times \frac{1\ mol\ CO_2}{44.0103\ g\ CO_2} \times \frac{1\ mol\ C}{1\ mol\ CO_2} = 1.43 \times 10^{-4}\ mol\ C$

(molar mass CO_2)

H) $2.58\ mg\ H_2O \times \frac{1\ g}{1000\ mg} \times \frac{1\ mol\ H_2O}{18.0157\ g\ H_2O} \times \frac{2\ mol\ H}{1\ mol\ H_2O} = 2.86 \times 10^{-4}\ mol\ H$

O) 1) mass O = mass ethyl butyrate − (mass C + mass H)

$= 2.78\ mg - \left[\left(1.43 \times 10^{-4}\ mol\ C \times \frac{12.0107\ g}{1\ mol\ C} \times \frac{1000\ mg}{1\ g}\right) + \left(2.86 \times 10^{-4}\ mol\ H \times \frac{1.00794\ g}{1\ mol\ H} \times \frac{1000\ mg}{1\ g}\right)\right]$

* Units must be same units to subtract

mass O = 2.78 mg − [(1.72 mg) + (.289 mg H)] = 0.77 mg O

2) Convert to moles: $.77\ mg\ O \times \frac{1\ g}{1000\ mg} \times \frac{1\ mol\ O}{15.9998\ g\ O} = 4.8 \times 10^{-5}\ mol\ O$ * smallest #

II. Molar ratios

$\frac{4.8 \times 10^{-5}\ mol\ O}{4.8 \times 10^{-5}\ mol\ O} = 1O$ $\quad \frac{2.86 \times 10^{-4}\ mol\ H}{4.8 \times 10^{-5}\ mol\ O} = 5.96 = 6H$ $\quad \frac{1.43 \times 10^{-4}\ mol\ C}{4.8 \times 10^{-5}\ mol\ O} = 2.98 = 3C$

empirical formula C_3H_6O